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## U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN NO. 117.

A. C. TRUE, Director.

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EXPERIMENTS ON THE EFFECT OF MUSCULAR WORK  
UPON THE DIGESTIBILITY OF FOOD AND  
THE METABOLISM OF NITROGEN.

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CONDUCTED AT THE  
UNIVERSITY OF TENNESSEE,  
1899-1900.

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By CHAS. E. WAIT, Ph. D., F. C. S.,

*Professor of Chemistry at the University of Tennessee.*WASHINGTON:  
GOVERNMENT PRINTING OFFICE.  
1902.

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A. C. TRUE, Director.

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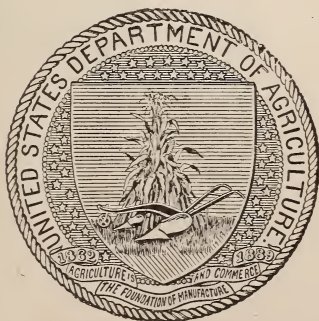
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## OFFICE OF EXPERIMENT STATIONS.

A. C. TRUE, Ph. D., *Director.*

E. W. ALLEN, Ph. D., *Assistant Director and Editor of Experiment Station Record.*

C. F. LANGWORTHY, Ph. D., *Editor and Expert on Foods and Animal Production.*

NUTRITION INVESTIGATIONS, MIDDLETOWN, CONN.

W. O. ATWATER, Ph. D., *Chief of Nutrition Investigations.*

C. D. WOODS, B. S., *Special Agent at Orono, Me.*

F. G. BENEDICT, Ph. D., *Physiological Chemist.*

R. D. MILNER, Ph. B., *Editorial Assistant.*

## LETTER OF TRANSMITTAL.

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U. S. DEPARTMENT OF AGRICULTURE,  
OFFICE OF EXPERIMENT STATIONS,  
*Washington, D. C., July 5, 1902.*

SIR: I have the honor to transmit herewith a report on experiments on the effect of muscular work upon the digestibility of food and the metabolism of nitrogen conducted at the University of Tennessee in 1899 and 1900 by Charles E. Wait, professor of chemistry, under the immediate supervision of Prof. W. O. Atwater, chief of nutrition investigations. These studies form a part of the nutrition investigations, conducted under the auspices of this Office, to gather information regarding the food habits in different regions, the comparative values of different foods, the laws of nutrition, and related topics. In making these investigations Professor Wait was assisted by Messrs. C. O. Hill, W. K. Hunter, C. A. Mooers, and C. G. Schenk, of the department of chemistry of the University of Tennessee. The present investigations supplement earlier work at the same institution on the effect of muscular work on digestion and metabolism, questions which are of great importance, and concerning which there is little information available. It is believed that the present investigation is a valuable contribution to the subject.

The report is therefore submitted with the recommendation that it be published as Bulletin No. 117 of this Office.

Respectfully,

A. C. TRUE,  
*Director.*

HON. JAMES WILSON,  
*Secretary of Agriculture.*





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# MUSCULAR WORK AND ITS EFFECT UPON DIGESTION AND METABOLISM

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## INTRODUCTION.

With a view to learning something of the food requirements when muscular work is performed and of the digestibility of the diet and the income and outgo of nitrogen under conditions of varying muscular work, experiments have been carried on for several years at the University of Tennessee. The effect of muscular work upon the metabolism of nitrogen has been often studied in the past, as has also the question of diet when different amounts of muscular work are performed. Many of the previous nutrition investigations conducted under the auspices of this Department have had to do with these problems.<sup>a</sup> It appears that comparatively few experiments with man have been made to determine the influence of muscular work upon the digestion of food.

The results of the earlier experiments on this subject at the University of Tennessee have been reported in previous publications of this Office.<sup>b</sup> The present bulletin reports the results of nine additional experiments (Nos. 17-25, inclusive) conducted in 1900, which were divided into three sets of three experiments each. With one exception, each of the experiments covered twelve consecutive days, being divided into three periods of four days each. In every case muscular work was performed during the second period, while in the first and third periods as little muscular work was performed as possible.

In the first series of experiments (Nos. 17-19) the diet furnished a normal amount of protein and energy, and was the same in all three periods. In the second series (experiments Nos. 20-22) the diet in the first and third, or rest periods, furnished several grams less nitrogen and 500-600 calories less energy than a normal diet. During the second or work period the nitrogen content of the ration was unchanged, while the energy value was increased some 500 or 600 calories. In other words, the energy was brought up to the normal. In the third series of experiments (Nos. 23-25) the diet was uniform throughout the experiment, and in both rest and work periods furnished less protein and less energy than a normal diet.

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<sup>a</sup> U. S. Dept. Agr., Office of Experiment Stations Buls. 75, 89, 98, and 109.

<sup>b</sup> U. S. Dept. Agr., Office of Experiment Stations Buls. 53 and 89.

The subjects of the experiments were the same three healthy young men with whom the earlier tests had been made.

The food consisted of such articles as gelatin, milk, oatmeal, potato chips, rice, coffee, butter, eggs, and sugar, combined in such a way as to form a simple mixed diet of reasonable palatability. The diet was somewhat simpler than in the experiments previously reported.<sup>a</sup>

The digestibility of the ration was determined by the usual methods, which have been described in earlier publications of this Office.<sup>b</sup> The food and feces were analyzed, the latter being separated by means of charcoal taken in gelatin capsules.

The income and outgo of nitrogen was also studied. In addition to determining the total amount of urine and its nitrogen content, determinations were made of the amount and proportions of nitrogen in the urine corresponding to eight-hour periods during the second or work periods, as it was believed that any effects of muscular work on the excretion of nitrogen might be thus more readily observed. Similar determinations were made during the third period to learn whether the muscular work produced effects which were noticeable after the work had ceased. In most of the experiments these determinations were also made for purposes of comparison in the first rest period.

The external muscular work consisted in walking up and down a hill 140 feet high on a smooth path. The amount of muscular work which can be measured in such cases is the product of the body weight of the subject, the number of feet which his body is vertically raised each trip, and the number of trips, that is, weight multiplied by number of trips uphill multiplied by 140 feet equals foot-pounds of work. So far as is known, the energy expended for the motion of forward progression has never been satisfactorily measured with man. The amount of work performed by a man walking downhill is also unknown. It is certain, therefore, that more work was performed by the subject than is shown by the method of calculation followed. While it is to be regretted that the total amount of work could not be accurately measured, the results are sufficient for the purposes of the experiments, since the object was to require of the subject an amount of muscular work sufficient to produce fatigue and to compare the results with different subjects under the experimental conditions. So far as an extended review of the literature shows, the factors which were not measured in these experiments have not been taken into account in similar experiments reported by other investigators.

#### **PREPARATION, SAMPLING, AND ANALYSIS OF FOOD MATERIALS.**

As stated above, the diet followed in these experiments was simple and made up of a comparatively small number of articles. The foods

<sup>a</sup> U. S. Dept. Agr., Office of Experiment Stations Buls. 53 and 89.

<sup>b</sup> U. S. Dept. Agr., Office of Experiment Stations Buls. 21 and 85.

chosen were of such a nature that it is believed little difficulty would be experienced in obtaining a comparatively large supply of practically uniform composition, a matter of considerable importance in experiments in which it is desired to have a diet furnishing uniform amounts of nutrients and energy. The milk, butter, coffee, sugar, rice, and eggs were the usual products. The bread was made from patent wheat flour and was the so-called Vienna loaf. The gelatin was one of the ordinary commercial products, as was also the rolled oats used. The potato chips were prepared by frying very thin slices of potato in deep fat until light brown. Care was taken to secure representative samples of all food materials for analysis. The milk was purchased fresh each day, an aliquot portion taken as a sample, and these portions united to form a composite sample for the whole period. The oatmeal was sampled before cooking. In the case of bread, representative slices from each loaf served as samples.

### COMPOSITION OF FOOD MATERIALS AND FECES.

The composition of the foods and feces was determined by the analytical methods adopted by the Association of Official Agricultural Chemists,<sup>a</sup> with such modifications as have been suggested by Atwater and Woods,<sup>b</sup> and with minor variations which experience in this laboratory has shown to be desirable.

The heats of combustion of the samples of food materials and excretory products were not determined in these experiments. The values for energy given in the tables of the different experiments were calculated. The energy of the food materials was calculated from the total nutrients of the diet by the factors 5.65 calories per gram of protein, 9.40 calories per gram of fat, and 4.15 calories per gram of carbohydrates.<sup>c</sup> The energy of the feces for the rest and work experiments was calculated from the total organic matters of the feces by use of the average heat of combustion per gram of feces in the rest and work experiments of 1897-1899, viz.,<sup>d</sup> 5.19 calories per gram in the rest experiments and 5.42 calories per gram in the work experiments. The energy of the urine was computed by assuming that for every gram of protein in the digested material there would be 1.25 calories of energy lost in the organic matter of the urine.<sup>e</sup>

Table 1 shows the composition of the food materials and Table 2 the composition of the water-free feces. The proportion of nitrogen in the food materials and feces is included in the tables, as well as the

<sup>a</sup> U. S. Dept. Agr., Division of Chemistry Bul. 46, revised.

<sup>b</sup> Connecticut (Storrs) Station Report, 1891, p. 47, and U. S. Dept. Agr., Office of Experiment Stations Bul. 21.

<sup>c</sup> Connecticut (Storrs) Station Report, 1899, p. 104.

<sup>d</sup> U. S. Dept. Agr., Office of Experiment Stations Bul. 89, p. 15.

<sup>e</sup> U. S. Dept. Agr., Office of Experiment Stations Bul. 53, p. 28.



protein which represents the total nitrogen multiplied by the factor 6.25. It is recognized that the use of this factor involves more or less error, especially in the case of cereals; but as it has been more generally used than any other factor in computing the results of digestion experiments it has been retained. Should it seem desirable at any time to recalculate the results, making use of other factors, this can be readily done from the statistics published in this report.

TABLE 1.—*Composition of food materials.*

Laboratory number.	Food materials.	Water.	Nitrogen.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
449	Eggs.....	73.67	2.08	13.00	11.17	.....	0.99
486	Butter.....	11.69	.22	1.39	83.86	.....	3.06
508	.....do.....	8.27	.24	1.56	87.43	.....	2.74
528	.....do.....	11.05	.30	1.89	84.79	.....	2.27
481	Milk.....	85.88	.59	3.69	4.61	5.10	.72
494	.....do.....	86.26	.55	3.44	4.54	5.02	.74
499	.....do.....	86.30	.57	3.56	4.46	4.86	.82
504	.....do.....	86.18	.58	3.63	4.72	4.67	.80
515	.....do.....	86.23	.56	3.50	4.94	4.85	.75
520	.....do.....	85.96	.56	3.50	4.94	4.85	.75
525	.....do.....	86.51	.55	3.44	4.65	4.63	.77
535	.....do.....	86.42	.54	3.38	4.65	4.82	.73
540	.....do.....	85.98	.54	3.38	5.02	4.83	.79
480	Gelatin.....	1.00	.75	4.69	.36	93.82	.13
482	Oatmeal.....	6.94	2.27	14.19	7.01	69.99	1.87
505	.....do.....	8.25	2.45	15.31	7.18	67.39	1.87
485	Rice.....	8.62	1.33	8.31	.41	82.16	.50
484	Wheat bread.....	32.49	1.52	9.51	1.17	55.96	.87
507	.....do.....	31.81	1.51	9.42	1.25	56.55	.97
527	.....do.....	31.81	1.59	9.94	1.27	55.92	1.06
483	Potato chips.....	4.88	.78	4.88	30.78	56.37	3.09
506	.....do.....	3.73	1.20	7.50	36.68	47.80	4.29
526	.....do.....	3.01	1.25	7.81	33.34	51.05	4.79
	Sugar.....	.....	.....	.....	.....	100.00	.....
	Coffee.....	.....	.....	.....	.....	.....	.....

TABLE 2.—*Composition of water-free substance of feces.*

Laboratory number.	Sample.	Nitrogen.	Protein (N×6.25).	Fat.	Carbohydrates.	Ash.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
490	Feces.....	4.77	29.83	15.72	29.05	25.40
491	.....do.....	4.98	31.13	25.53	23.78	19.56
492	.....do.....	4.69	29.32	24.24	26.73	19.71
495	.....do.....	4.98	31.13	14.60	29.11	25.16
496	.....do.....	4.96	31.02	25.69	23.41	19.88
497	.....do.....	4.44	27.77	30.50	21.65	20.08
500	.....do.....	4.92	30.78	13.51	29.16	26.55
501	.....do.....	5.10	31.89	23.98	23.03	21.10
502	.....do.....	4.83	30.22	23.97	25.40	20.41
511	.....do.....	4.76	29.76	22.91	19.29	28.04
512	.....do.....	5.00	31.24	30.38	15.30	23.08
513	.....do.....	4.71	29.40	31.99	16.93	21.68
516	.....do.....	4.88	30.48	22.53	21.98	25.01
517	.....do.....	4.87	30.44	33.23	14.18	22.15
518	.....do.....	4.59	28.67	36.13	15.67	19.53
521	.....do.....	5.00	31.27	19.66	22.43	26.64
522	.....do.....	4.93	30.80	29.23	16.58	23.39
523	.....do.....	4.82	30.14	25.49	22.03	22.34
531	.....do.....	4.91	30.71	18.38	23.81	27.10
532	.....do.....	5.09	31.80	18.64	26.76	22.80
533	.....do.....	4.85	30.33	16.57	28.91	24.19
536	.....do.....	4.93	30.84	20.07	22.66	26.43
537	.....do.....	5.12	32.01	27.55	18.99	21.45
538	.....do.....	5.02	31.35	28.13	18.03	22.49
541	.....do.....	4.86	30.39	21.77	20.59	27.25
542	.....do.....	5.20	32.49	27.13	19.43	20.95
543	.....do.....	4.87	30.41	34.03	14.55	21.01



## DETAILS OF THE EXPERIMENTS CARRIED ON IN 1899-1900.

The experiments recorded in the present report were conducted in the winter of 1899-1900, and were so arranged that each experiment was carried on with the three different subjects simultaneously. The supper preceding each experiment consisted largely of bread and milk, and the experimental period in every case commenced with breakfast. With this meal the lampblack used to color the feces and to permit a separation of portions pertaining to the diet under investigation was taken. In the earlier investigations the experiment proper was preceded by a period in which the diet was adjusted so that the subject was in nitrogen equilibrium. This plan was not followed in the present investigation, as (judging by the experience then gained) it was not necessary.

### EXPERIMENT NO. 17.

This experiment was carried on with a chemist 30 years of age, in good health. The experiment was divided into three periods of four days each. During the second period the subject made 74 trips up and down hill. This was calculated as equivalent to 1,617,122 foot-pounds or 55,876 kilogrammeters of work. The mechanical equivalent of one calorie is, in round numbers, 3,100 foot-pounds. The heat equivalent for the work measured for the four days was, therefore, 130 calories, or 32 calories per day. As previously stated, the actual work performed must have been considerably more than the amount thus estimated.

*Subject.*—Chemist, 30 years of age.

*Weight (without clothing).*—At the beginning of the experiment 68.6 kilograms (151 pounds); at the end of the first period 68.2 kilograms (150 pounds). During the remainder of the experiment the weight remained unchanged.

*Duration.*—The experiment began with breakfast, December 9; the second period with breakfast, December 13, and the third period with breakfast, December 17. Each period, therefore, occupied four days.

TABLE 3.—Results of experiment No. 17.

Laboratory number.	Food materials.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion calculated.
<b>FIRST PERIOD (REST).</b>									
<i>Digestion experiment No. 206.</i>									
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
449	Eggs.....	364	88	7.57	47	41	.....	4	.....
486	Butter.....	120	103	.26	2	101	.....	4	.....
481	Milk.....	8,000	1,072	47.20	295	369	408	58	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
482	Oatmeal.....	320	291	7.26	45	22	224	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
484	Bread.....	1,200	800	18.24	114	14	672	10	.....
483	Potato chips.....	40	37	.31	2	12	23	1	.....
	Sugar.....	320	320	.....	.....	.....	320	.....	.....
	Coffee.....	800	2	.32	2	.....	.....	.....	.....
	Total.....	.....	2,921	83.51	522	559	1,840	84	15,839
490	Feces (water-free).....	147	110	7.01	44	23	43	37	571
	Urine.....	7,020	.....	70.25	.....	.....	.....	.....	597
	Amount digested.....	.....	2,811	76.50	478	536	1,797	47	14,671
	Coefficients of digestibility (per cent).....	.....	96.2	91.6	91.6	95.9	97.7	56.0	92.6
<b>SECOND PERIOD (WORK).</b>									
<i>Digestion experiment No. 207.</i>									
449	Eggs.....	364	88	7.57	47	41	.....	4	.....
486	Butter.....	120	103	.26	2	101	.....	4	.....
494	Milk.....	8,000	1,040	44.00	275	363	402	59	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
482	Oatmeal.....	320	291	7.26	45	22	224	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
484	Bread.....	1,200	800	18.24	114	14	672	10	.....
483	Potato chips.....	40	37	.31	2	12	23	1	.....
	Sugar.....	320	320	.....	.....	.....	320	.....	.....
	Coffee.....	800	2	.32	2	.....	.....	.....	.....
	Total.....	.....	2,889	80.31	502	553	1,834	85	15,646
495	Feces (water-free).....	140	105	6.97	44	20	41	35	569
	Urine.....	5,837	.....	71.68	.....	.....	.....	.....	572
	Amount digested.....	.....	2,784	73.34	458	533	1,793	50	14,505
	Coefficients of digestibility (per cent).....	.....	96.4	91.3	91.2	96.4	97.8	58.8	92.7
<b>THIRD PERIOD (REST).</b>									
<i>Digestion experiment No. 208.</i>									
449	Eggs.....	364	88	7.57	47	41	.....	4	.....
486	Butter.....	120	103	.26	2	101	.....	4	.....
499	Milk.....	8,000	1,031	45.60	285	357	389	66	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
482	Oatmeal.....	320	291	7.26	45	22	224	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
484	Bread.....	1,200	800	18.24	114	14	672	10	.....
483	Potato chips.....	40	37	.31	2	12	23	1	.....
	Sugar.....	320	320	.....	.....	.....	320	.....	.....
	Coffee.....	800	2	.32	2	.....	.....	.....	.....
	Total.....	.....	2,880	81.91	512	547	1,821	92	15,592
500	Feces (water-free).....	130	96	6.40	40	18	38	34	498
	Urine.....	7,233	.....	70.43	.....	.....	.....	.....	590
	Amount digested.....	.....	2,784	75.51	472	529	1,783	58	14,504
	Coefficients of digestibility (per cent).....	.....	96.7	92.2	92.2	96.7	97.9	63.0	93.0

Throughout this experiment the urine was collected in portions corresponding to eight-hour intervals. The results for the first period (rest) follow:

TABLE 4.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 206).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine .....grams..	550	710	602	1,862
Weight of nitrogen.....do....	6.05	6.82	5.42	18.29
Per cent of nitrogen.....	1.10	.96	.90	.....
Second day:				
Weight of urine .....grams..	1,112	688	417	2,217
Weight of nitrogen.....do....	6.34	6.26	4.63	17.23
Per cent of nitrogen.....	.57	.91	1.11	.....
Third day:				
Weight of urine .....grams..	508	683	357	1,548
Weight of nitrogen.....do....	5.54	6.76	4.68	16.98
Per cent of nitrogen.....	1.09	.99	1.31	.....
Fourth day:				
Weight of urine .....grams..	385	633	375	1,393
Weight of nitrogen.....do....	5.54	7.22	4.99	17.75
Per cent of nitrogen.....	1.44	1.14	1.33	.....

The quantity of urine eliminated and its nitrogen content during the second or work period are shown in the following table:

TABLE 5.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 207).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine .....grams..	358	567	365	1,290
Weight of nitrogen.....do....	5.76	6.46	5.04	17.26
Per cent of nitrogen.....	1.61	1.14	1.38	.....
Second day:				
Weight of urine .....grams..	430	593	313	1,336
Weight of nitrogen.....do....	5.98	7.18	4.41	17.57
Per cent of nitrogen.....	1.39	1.21	1.41	.....
Third day:				
Weight of urine .....grams..	503	625	395	1,523
Weight of nitrogen.....do....	6.29	7.00	5.41	18.70
Per cent of nitrogen.....	1.25	1.12	1.37	.....
Fourth day:				
Weight of urine .....grams..	850	469	369	1,688
Weight of nitrogen.....do....	6.72	6.52	4.91	18.15
Per cent of nitrogen.....	.79	1.39	1.33	.....

During the third period, which was, like the first, a period of rest, the amount of urine eliminated and its nitrogen content were as follows:

TABLE 6.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 208).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine.....grams..	567	942	463	1,972
Weight of nitrogen.....do.....	6.41	6.78	4.63	17.82
Per cent of nitrogen.....	1.13	.72	1.00	.....
Second day:				
Weight of urine.....grams..	635	543	495	1,673
Weight of nitrogen.....do.....	5.52	6.46	5.10	17.08
Per cent of nitrogen.....	.87	1.19	1.03	.....
Third day:				
Weight of urine.....grams..	568	663	542	1,773
Weight of nitrogen.....do.....	5.68	6.90	5.42	18.00
Per cent of nitrogen.....	1.00	1.04	1.00	.....
Fourth day:				
Weight of urine.....grams..	653	688	474	1,815
Weight of nitrogen.....do.....	5.81	6.60	5.12	17.53
Per cent of nitrogen.....	.89	.96	1.08	.....

The above data regarding the income of nitrogen in the food and the excretion of nitrogen in the urine and feces served for computing the average balance of the income and outgo of this element. The effect of muscular work on the excretion of nitrogen is discussed when the experiments are considered as a whole. The nitrogen balance follows:

TABLE 7.—*Daily income and outgo of nitrogen in experiment No. 17.*

Periods.	Time.	Nitrogen.			
		In food.	In feces.	In urine.	Gain.
	<i>Days.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
First period, rest.....	4	20.88	1.75	17.56	1.57
Second period, work.....	4	20.08	1.74	17.92	.42
Third period, rest.....	4	20.48	1.60	17.61	1.27

### EXPERIMENT NO. 18.

This experiment was carried on at the same time as experiment No. 17. The subject, a chemist, 23 years of age, was in normal health. During the first and third periods of the experiment little or no external muscular work was performed. During the second period the subject made 80 trips up and down hill. This was calculated to furnish 1,439,100 foot-pounds or 48,849 kilogrammeters of work, equivalent to 114 calories, or an average of 28 calories per day.

*Subject.*—Chemist B, 23 years of age.

*Weight (without clothing).*—At the beginning of the experiment, 55.2 kilograms (121½ pounds); at the end of the first period and the beginning of the second period, 56.1 kilograms (123½ pounds); at the end of the second and the beginning of the third period, 56.4 kilograms (124 pounds); at the close of the experiment, 56.6 kilograms (124½ pounds).

*Duration.*—The experiment began with breakfast December 9, and the first period continued four days. The second period began with breakfast December 3 and continued four days. The third period began with breakfast December 17 and continued four days.



TABLE 8.—*Results of experiment No. 18.*

Laboratory number.	Food materials.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion calculated.
<b>FIRST PERIOD (REST).</b>									
<i>Digestion experiment No. 209.</i>									
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
449	Eggs.....	606	147	12.60	79	68	.....	6	.....
486	Butter.....	120	103	.26	2	101	.....	4	.....
481	Milk.....	6,000	804	35.40	221	277	306	43	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
482	Oatmeal.....	320	291	7.26	45	22	224	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
484	Bread.....	1,000	667	15.20	95	12	560	9	.....
483	Potato chips.....	120	111	.94	6	37	68	4	.....
	Sugar.....	400	400	.....	.....	.....	400	.....	.....
	Coffee.....	400	1	.16	.1	.....	.....	.....	.....
	Total.....	.....	2,732	74.17	464	517	1,751	73	14,749
491	Feces(water-free)	121	97	6.03	37	31	29	24	503
	Urine.....	4,981	.....	52.02	.....	.....	.....	.....	534
	Amount digested.....	.....	2,635	68.14	427	486	1,722	49	13,712
	Coefficients of digestibility (per cent).....	.....	96.5	91.9	92.0	94.0	98.3	67.1	93.0
<b>SECOND PERIOD (WORK).</b>									
<i>Digestion experiment No. 210.</i>									
449	Eggs.....	606	147	12.60	79	68	.....	6	.....
486	Butter.....	120	103	.26	2	101	.....	4	.....
494	Milk.....	6,000	780	33.00	206	273	301	44	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
482	Oatmeal.....	320	291	7.26	45	22	224	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
484	Bread.....	1,000	667	15.20	95	12	560	9	.....
483	Potato chips.....	120	111	.94	6	37	68	4	.....
	Sugar.....	400	400	.....	.....	.....	400	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....	.....	2,708	71.77	449	513	1,746	74	14,605
496	Feces(water-free)	122	98	6.05	38	31	29	24	531
	Urine.....	4,383	.....	57.12	.....	.....	.....	.....	514
	Amount digested.....	.....	2,610	65.72	411	482	1,717	50	13,560
	Coefficients of digestibility (per cent).....	.....	96.4	91.6	91.5	94.0	98.3	67.6	92.9
<b>THIRD PERIOD (REST).</b>									
<i>Digestion experiment No. 211.</i>									
449	Eggs.....	606	147	12.60	79	68	.....	6	.....
486	Butter.....	120	103	.26	2	101	.....	4	.....
499	Milk.....	6,000	773	34.20	214	268	291	49	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
482	Oatmeal.....	320	291	7.26	45	22	224	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
484	Bread.....	1,000	667	15.20	95	12	560	9	.....
483	Potato chips.....	120	111	.94	6	37	68	4	.....
	Sugar.....	400	400	.....	.....	.....	400	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....	.....	2,701	72.97	457	508	1,736	79	14,561
501	Feces(water-free)	123	97	6.27	39	30	28	26	503
	Urine.....	5,068	.....	56.70	.....	.....	.....	.....	522
	Amount digested.....	.....	2,604	66.70	418	478	1,708	53	13,536
	Coefficients of digestibility (per cent).....	.....	96.4	91.4	91.5	94.1	98.4	67.1	93.0

As in the preceding experiment, the urine was collected in the three periods in portions corresponding to eight-hour intervals. The data for the urine in the first period follows:

TABLE 9.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 209).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 p. m.	Total.
First day:				
Weight of urine.....grams..	530	325	270	1,125
Weight of nitrogen.....do....	4.24	4.23	3.73	12.20
Per cent of nitrogen.....	.80	1.30	1.38	.....
Second day:				
Weight of urine.....grams..	908	562	220	1,690
Weight of nitrogen.....do....	5.81	4.66	3.23	13.70
Per cent of nitrogen.....	.64	.83	1.47	.....
Third day:				
Weight of urine.....grams..	478	281	260	1,019
Weight of nitrogen.....do....	4.06	3.96	3.93	11.95
Per cent of nitrogen.....	.85	1.41	1.51	.....
Fourth day:				
Weight of urine.....grams..	574	338	235	1,147
Weight of nitrogen.....do....	5.51	4.83	3.83	14.17
Per cent of nitrogen.....	.96	1.43	1.63	.....

The total amount of urine and its nitrogen content eliminated during the second or work period follows:

TABLE 10.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 210).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine.....grams..	510	380	190	1,080
Weight of nitrogen.....do....	5.46	5.66	3.14	14.26
Per cent of nitrogen.....	1.07	1.49	1.65	.....
Second day:				
Weight of urine.....grams..	545	259	241	1,045
Weight of nitrogen.....do....	5.67	4.20	3.88	13.75
Per cent of nitrogen.....	1.04	1.62	1.61	.....
Third day:				
Weight of urine.....grams..	532	295	225	1,052
Weight of nitrogen.....do....	5.91	4.48	3.94	14.33
Per cent of nitrogen.....	1.11	1.52	1.75	.....
Fourth day:				
Weight of urine.....grams..	575	436	195	1,206
Weight of nitrogen.....do....	6.15	5.14	3.49	14.78
Per cent of nitrogen.....	1.07	1.18	1.79	.....



The third period like the first was a period of rest. The urine eliminated in periods corresponding to eight-hour intervals, and its nitrogen content, is shown in the following table:

TABLE 11.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 211).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine.....grams..	503	563	285	1,351
Weight of nitrogen.....do ..	5.68	5.24	3.79	14.71
Per cent of nitrogen.....	1.13	.93	1.33	.....
Second day:				
Weight of urine.....grams..	723	367	242	1,332
Weight of nitrogen.....do ..	5.49	4.84	3.56	13.89
Per cent of nitrogen.....	.76	1.32	1.47	.....
Third day:				
Weight of urine.....grams..	545	347	271	1,163
Weight of nitrogen.....do ..	5.45	4.55	3.98	13.98
Per cent of nitrogen.....	1.00	1.31	1.47	.....
Fourth day:				
Weight of urine.....grams..	632	403	187	1,222
Weight of nitrogen.....do ..	5.69	5.08	3.35	14.12
Per cent of nitrogen.....	.90	1.26	1.79	.....

From the data recorded above the balance of income and outgo of nitrogen was determined. The results follow:

TABLE 12.—*Daily income and outgo of nitrogen in experiment No. 18.*

Period.	Time.	Nitrogen.			
		In food.	In feces.	In urine.	Gain.
	Days.	Grams.	Grams.	Grams.	Grams.
First period, rest .....	4	18.54	1.51	13.01	4.02
Second period, work .....	4	17.94	1.51	14.28	2.15
Third period, rest .....	4	18.24	1.57	14.18	2.49

### EXPERIMENT NO. 19.

This experiment was carried on with a student, C, age 22 years, and in good health. In the first and third periods as little muscular work was performed as possible. During the second period the subject made 80 trips up and down a hill. This was calculated to furnish 1,471,080 foot-pounds, or 50,992 kilogrammeters, equivalent to a total of 119 calories, or 30 calories per day.

*Subject.*—Student C, 22 years of age.

*Weight (without clothing).*—At the beginning of the experiment, 63.0 kilograms (138½ pounds); at the close of the first period, 62.7 kilograms (138 pounds). During the second and third periods the weight remained unchanged.

*Duration.*—The experiment began with breakfast December 9; the first period covered four days; the second began with breakfast December 13 and covered four days; the third began with breakfast December 17 and covered only three days.

TABLE 13.—Results of experiment No. 19.

Laboratory number.	Food materials.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion calculated.
<b>FIRST PERIOD (REST).</b>									
<i>Digestion experiment No. 212.</i>									
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
449	Eggs.....	519	125	10.80	67	58	.....	5	.....
486	Butter.....	120	103	.26	2	101	.....	4	.....
481	Milk.....	6,000	804	35.40	221	277	306	43	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
482	Oatmeal.....	320	291	7.26	45	22	224	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
484	Bread.....	1,200	800	18.24	114	14	672	10	.....
483	Potato chips.....	160	147	1.25	8	49	90	5	.....
	Sugar.....	400	400	.....	.....	.....	400	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....	.....	2,879	75.72	473	521	1,885	74	15,392
492	Feces(water-free)	123	99	5.77	36	30	33	24	514
	Urine.....	4,468	.....	57.16	.....	.....	.....	.....	546
	Amount digested.....	.....	2,780	69.95	437	491	1,852	50	14,332
	Coefficients of digestibility (per cent).....	.....	96.6	92.4	92.4	94.3	98.3	67.6	93.1
<b>SECOND PERIOD (WORK).</b>									
<i>Digestion experiment No. 213.</i>									
449	Eggs.....	519	125	10.80	67	58	.....	5	.....
486	Butter.....	120	103	.26	2	101	.....	4	.....
494	Milk.....	6,000	780	33.00	206	273	301	44	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
482	Oatmeal.....	320	291	7.26	45	22	224	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
484	Bread.....	1,200	800	18.24	114	14	672	10	.....
483	Potato chips.....	160	147	1.25	8	49	90	5	.....
	Sugar.....	400	400	.....	.....	.....	400	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....	.....	2,855	73.32	458	517	1,880	75	15,250
497	Feces(water-free)	123	99	5.46	34	38	27	25	537
	Urine.....	4,040	.....	65.75	.....	.....	.....	.....	530
	Amount digested.....	.....	2,756	67.86	424	479	1,853	50	14,183
	Coefficients of digestibility (per cent).....	.....	96.5	92.6	92.6	92.7	98.6	66.7	93.0
<b>THIRD PERIOD (REST).</b>									
<i>Digestion experiment No. 214.</i>									
449	Eggs.....	389	94	8.09	51	43	.....	4	.....
486	Butter.....	90	76	.20	1	75	.....	3	.....
499	Milk.....	4,500	580	25.65	160	201	219	37	.....
480	Gelatin.....	75	74	.56	4	.....	70	.....	.....
482	Oatmeal.....	240	219	5.45	34	17	168	4	.....
485	Rice.....	90	82	1.20	8	.....	74	.....	.....
484	Bread.....	900	600	13.68	86	10	504	8	.....
483	Potato chips.....	120	111	.94	6	37	68	4	.....
	Sugar.....	300	300	.....	.....	.....	300	.....	.....
	Coffee.....	300	1	.12	1	.....	.....	.....	.....
	Total.....	.....	2,137	55.89	351	383	1,403	60	11,405
502	Feces(water-free)	84	67	4.06	25	20	22	17	348
	Urine.....	4,245	.....	50.31	.....	.....	.....	.....	407
	Amount digested.....	.....	2,070	51.83	326	363	1,381	43	10,650
	Coefficients of digestibility (per cent).....	.....	96.9	92.7	92.9	94.8	98.4	71.7	93.4

In all three periods of this experiment the urine was collected in portions corresponding to eight-hour periods, the amount and its nitrogen content being determined. Results from the first (rest) period follow:

TABLE 14.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 212).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine.....grams..	447	330	344	1,121
Weight of nitrogen.....do....	5.45	5.68	4.20	15.33
Per cent of nitrogen.....	1.22	1.72	1.22	.....
Second day:				
Weight of urine.....grams..	575	557	246	1,378
Weight of nitrogen.....do....	6.10	4.01	3.57	13.68
Per cent of nitrogen.....	1.06	.72	1.45	.....
Third day:				
Weight of urine.....grams..	275	333	203	811
Weight of nitrogen.....do....	4.10	5.56	3.19	12.85
Per cent of nitrogen.....	1.49	1.67	1.57	.....
Fourth day:				
Weight of urine.....grams..	358	500	300	1,158
Weight of nitrogen.....do....	5.48	6.40	3.42	15.30
Per cent of nitrogen.....	1.53	1.28	1.14	.....

The amount of urine eliminated during the second (work) period and its nitrogen content was as follows:

TABLE 15.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 213).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine.....grams..	385	311	280	976
Weight of nitrogen.....do....	5.27	5.22	4.82	15.31
Per cent of nitrogen.....	1.37	1.68	1.72	.....
Second day:				
Weight of urine.....grams..	337	345	203	885
Weight of nitrogen.....do....	5.66	6.83	3.53	16.02
Per cent of nitrogen.....	1.68	1.98	1.74	.....
Third day:				
Weight of urine.....grams..	367	378	263	1,008
Weight of nitrogen.....do....	6.17	6.35	4.63	17.15
Per cent of nitrogen.....	1.68	1.68	1.76	.....
Fourth day:				
Weight of urine.....grams..	507	387	277	1,171
Weight of nitrogen.....do....	6.54	5.61	5.12	17.27
Per cent of nitrogen.....	1.29	1.45	1.85	.....

The details of the elimination of nitrogen during the third (rest) period, which covered only three days, are given in the following table:

TABLE 16.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 214).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine .....	382	658	398	1,438
Weight of nitrogen .....	5.77	6.51	5.25	17.53
Per cent of nitrogen .....	1.51	.99	1.32	.....
Second day:				
Weight of urine .....	535	443	390	1,368
Weight of nitrogen .....	5.89	6.42	4.06	16.37
Per cent of nitrogen .....	1.10	1.45	1.04	.....
Third day:				
Weight of urine .....	450	531	458	1,439
Weight of nitrogen .....	5.76	6.21	4.44	16.41
Per cent of nitrogen .....	1.28	1.17	.97	.....

The nitrogen balance was as follows:

TABLE 17.—*Daily income and outgo of nitrogen in experiment No. 19.*

Periods.	Time.	Nitrogen.			
		In food.	In feces.	In urine.	Gain.
	Days.	Grams.	Grams.	Grams.	Grams.
First period, rest .....	4	18.93	1.44	14.29	3.20
Second period, work .....	4	18.33	1.37	16.44	.52
Third period, rest .....	3	18.63	1.35	16.77	.51

## EXPERIMENT NO. 20.

This experiment began a second set with the same subjects as in experiments Nos. 17, 18, and 19. In this set the diet in the first and third periods contained less than the normal amount of protein and energy, and during these periods little, if any, muscular work was performed. In the second period considerable muscular work was performed and the energy value of the diet was increased until it was equal in this respect to a normal diet. During the second period the subject of experiment No. 20 made the trip up and down hill fifty-two times. This, according to the method of calculation followed, gave 1,136,356 foot-pounds, or 49,421 kilogrammeters, equivalent to 92 calories, or 23 calories per day.

*Subject.*—Chemist A, 30 years of age.

*Weight (without clothing).*—At the beginning of the experiment 69.8 kilograms (153.5 pounds); at the end of the first period 68.6 kilograms (151 pounds). During the second and third period the weight did not change.

*Duration.*—The experiment began with breakfast March 8, the first period covered four days. The second period began with breakfast March 12, and covered four days. The third period began with breakfast March 16, and covered four days.



TABLE 18.—Results of experiment No. 20.

Laboratory number.	Food materials.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion calculated.
FIRST PERIOD (REST).									
<i>Digestion experiment No. 215.</i>									
		Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Grams.	Calories.
449	Eggs.....	364	88	7.57	47	41	.....	4	.....
508	Butter.....	40	36	.10	1	35	.....	1	.....
504	Milk.....	8,000	1,042	46.40	290	378	374	64	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	320	288	7.84	49	23	216	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
507	Bread.....	840	565	12.68	79	11	475	8	.....
506	Potato chips.....	40	37	.48	3	15	19	2	.....
	Sugar.....	240	240	.....	.....	.....	240	.....	.....
	Coffee.....	800	2	.32	2	.....	.....	.....	.....
	Total.....	.....	2,506	77.74	486	503	1,517	86	13,769
511	Feces (water-free)	128	92	6.09	38	29	25	36	477
	Urine.....	6,705	.....	71.90	.....	.....	.....	.....	560
	Amount digested.	.....	2,414	71.65	448	474	1,492	50	12,732
	Coefficients of digestibility (per cent).....	.....	96.3	92.2	92.2	94.2	98.4	58.1	92.5
SECOND PERIOD (WORK).									
<i>Digestion experiment No. 216.</i>									
449	Eggs.....	364	88	7.57	47	41	.....	4	.....
508	Butter.....	180	160	.43	3	157	.....	5	.....
515	Milk.....	7,408	963	41.48	259	367	337	56	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	320	288	7.84	49	23	216	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
507	Bread.....	1,000	672	15.10	94	12	566	10	.....
506	Potato chips.....	100	92	1.20	7	37	48	4	.....
	Sugar.....	420	420	.....	.....	.....	420	.....	.....
	Coffee.....	800	2	.32	2	.....	.....	.....	.....
	Total.....	.....	2,893	76.29	476	637	1,780	86	16,063
516	Feces (water-free)	130	98	6.34	40	29	29	32	531
	Urine.....	3,858	.....	66.99	.....	.....	.....	.....	545
	Amount digested.	.....	2,795	69.95	436	608	1,751	54	14,987
	Coefficients of digestibility (per cent).....	.....	96.6	91.7	91.6	95.5	98.4	62.8	93.3
THIRD PERIOD (REST).									
<i>Digestion experiment No. 217.</i>									
449	Eggs.....	364	88	7.57	47	41	.....	4	.....
508	Butter.....	40	36	.10	1	35	.....	1	.....
520	Milk.....	8,000	1,063	44.80	280	395	388	60	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	320	288	7.84	49	23	216	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
507	Bread.....	840	565	12.68	79	11	475	8	.....
506	Potato chips.....	40	37	.48	3	15	19	2	.....
	Sugar.....	240	240	.....	.....	.....	240	.....	.....
	Coffee.....	800	2	.32	2	.....	.....	.....	.....
	Total.....	.....	2,527	76.14	476	520	1,531	82	13,961
521	Feces (water-free)	130	95	6.50	41	25	29	35	493
	Urine.....	6,971	.....	69.80	.....	.....	.....	.....	544
	Amount digested.	.....	2,432	69.64	435	495	1,502	47	12,894
	Coefficients of digestibility (per cent).....	.....	96.2	91.5	91.4	95.2	98.1	57.3	92.6

In the second set of experiments the daily urine was collected in one portion during the first (work) period. On the first day of first period of experiment No. 20 the total urine was 1,890 grams and its nitrogen content 0.96 per cent, or 18.1 grams; on the second day 1,750 grams, with a nitrogen content of 1.02 per cent, or 17.9 grams; on the third day 1,645 grams, with a nitrogen content of 1.13 per cent, or 18.6 grams; and on the fourth day 1,420 grams, with a nitrogen content of 1.22 per cent, or 17.3 grams. The total nitrogen eliminated was therefore 73.9 grams.

During the second (work) period the urine was collected in portions corresponding to eight-hour intervals. The results follow:

TABLE 19.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 216).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine .....grams..	345	303	336	984
Weight of nitrogen.....do.....	5.00	5.48	5.38	15.86
Per cent of nitrogen .....	1.45	1.81	1.60	.....
Second day:				
Weight of urine .....grams..	305	353	245	903
Weight of nitrogen.....do.....	4.70	7.17	4.70	16.57
Per cent of nitrogen .....	1.54	2.03	1.92	.....
Third day:				
Weight of urine .....grams..	282	281	295	858
Weight of nitrogen.....do.....	5.16	5.99	5.40	16.55
Per cent of nitrogen .....	1.83	2.13	1.83	.....
Fourth day:				
Weight of urine .....grams..	358	350	405	1,113
Weight of nitrogen.....do.....	6.19	5.99	5.83	18.01
Per cent of nitrogen .....	1.73	1.71	1.44	.....

During the third (rest) period the urine was also collected in portions corresponding to eight-hour intervals. The amount of urine and its nitrogen content are shown in Table 20, which follows:

TABLE 20.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 217).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine .....grams..	448	1,005	473	1,926
Weight of nitrogen.....do.....	5.82	6.53	5.16	17.51
Per cent of nitrogen .....	1.30	.65	1.09	.....
Second day:				
Weight of urine .....grams..	725	613	381	1,719
Weight of nitrogen.....do.....	6.53	6.25	4.84	17.62
Per cent of nitrogen .....	.90	1.02	1.27	.....
Third day:				
Weight of urine .....grams..	770	645	422	1,837
Weight of nitrogen.....do.....	6.62	6.39	5.02	18.03
Per cent of nitrogen .....	.86	.99	1.19	.....
Fourth day:				
Weight of urine .....grams..	397	794	298	1,489
Weight of nitrogen.....do.....	5.56	8.58	2.50	16.64
Per cent of nitrogen .....	1.40	1.08	.84	.....



From the data given in the preceding tables the balance of income and outgo of nitrogen was calculated as follows:

TABLE 21.—*Daily income and outgo of nitrogen in experiment No. 20.*

Periods.	Time.	Nitrogen.			
		In food.	In feces.	In urine.	Gain (+) or loss (-).
	<i>Days.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
First period, rest .....	4	19.43	1.52	17.98	-0.07
Second period, work .....	4	19.07	1.59	16.75	+ .73
Third period, rest .....	4	19.04	1.62	17.45	- .03

### EXPERIMENT NO. 21.

The experimental conditions were the same as in the preceding experiment. The subject, a chemist, was 23 years of age and in good health. During the work period the subject made the trip up and down hill 68 times. This was calculated to yield 1,223,235 foot-pounds, or 42,422 kilogrammeters, equivalent to 99 calories, or 25 calories per day. The results of the digestion experiment follow:

*Subject.*—Chemist B, 23 years of age.

*Weight (without clothing).*—At the beginning of the experiment, 56.4 kilograms (124 pounds); at the end of the first period and the beginning of the second period, 55.9 kilograms (123 pounds); at the end of the second and the beginning of the third period, 56.4 kilograms (124 pounds); at the end of the experiment, 56.1 kilograms (123½ pounds).

*Duration.*—The periods each covered four days and began with breakfast March 8, 12, and 16, respectively.

TABLE 22.—*Results of experiment No. 21.*

Laboratory number.	Food materials.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heats of combustion calculated.
<b>FIRST PERIOD (REST).</b>									
<i>Digestion experiment No. 218.</i>									
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
449	Eggs.....	608	147	12.65	79	68	.....	6	.....
508	Butter.....	40	36	.10	1	35	.....	1	.....
504	Milk.....	6,000	781	34.80	218	283	280	48	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	320	288	7.84	49	23	216	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
507	Bread.....	640	430	9.66	60	8	362	6	.....
506	Potato chips.....	120	110	1.44	9	44	57	5	.....
	Sugar.....	320	320	.....	.....	.....	320	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....	.....	2,321	69.00	432	461	1,428	73	12,701
512	Feces (water-free).....	115	88	5.75	36	35	17	26	457
	Urine.....	4,497	.....	48.89	.....	.....	.....	.....	495
	Amount digested.....	.....	2,233	63.25	396	426	1,411	47	11,749
	Coefficients of digestibility (per cent).....	.....	96.2	91.7	91.7	92.4	98.8	64.4	92.5
<b>SECOND PERIOD (WORK).</b>									
<i>Digestion experiment No. 219.</i>									
449	Eggs.....	608	147	12.65	79	68	.....	6	.....
508	Butter.....	180	160	.43	3	157	.....	5	.....
515	Milk.....	5,408	703	30.28	189	268	246	41	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	320	288	7.84	49	23	216	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
507	Bread.....	800	537	12.08	75	10	452	8	.....
506	Potato chips.....	180	166	2.16	14	66	86	8	.....
	Sugar.....	500	500	.....	.....	.....	500	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....	.....	2,710	67.95	425	592	1,693	75	14,992
517	Feces (water-free).....	111	87	5.41	34	37	16	25	472
	Urine.....	4,061	.....	54.90	.....	.....	.....	.....	489
	Amount digested.....	.....	2,623	62.54	391	555	1,677	50	14,031
	Coefficients of digestibility (per cent).....	.....	96.8	92.0	92.0	93.8	99.1	66.7	93.6
<b>THIRD PERIOD (REST).</b>									
<i>Digestion experiment No. 220.</i>									
449	Eggs.....	608	147	12.65	79	68	.....	6	.....
508	Butter.....	40	36	.10	1	35	.....	1	.....
520	Milk.....	6,000	797	33.60	210	296	291	45	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	320	288	7.84	49	23	216	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
507	Bread.....	640	430	9.66	60	8	362	6	.....
506	Potato chips.....	120	110	1.44	9	44	57	5	.....
	Sugar.....	320	320	.....	.....	.....	320	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....	.....	2,337	67.80	424	474	1,439	70	12,823
522	Feces (water-free).....	114	87	5.62	35	33	19	27	452
	Urine.....	4,624	.....	54.65	.....	.....	.....	.....	486
	Amount digested.....	.....	2,250	62.18	389	441	1,420	43	11,885
	Coefficients of digestibility (per cent).....	.....	96.3	91.7	91.7	93.0	98.7	61.4	92.7

On the first day of the first (rest) period 1,413 grams of urine was eliminated, containing 0.72 per cent, or 10.2 grams nitrogen; on the second day, 1,137 grams urine, containing 1.03 per cent, or 11.7 grams nitrogen; on the third day, 943 grams urine, with 1.3 per cent, or 12.4 grams nitrogen; and on the fourth day, 1,004 grams urine, containing 1.45 per cent, or 14.6 grams nitrogen. The total nitrogen eliminated was, therefore, 48.9 grams, or 12.2 grams per day.

During the second (work) period the urine was collected in portions corresponding to eight-hour intervals and its nitrogen content determined. The details follow:

TABLE 23.—Amount of nitrogen eliminated in the urine (digestion experiment No. 219).

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine .....grams..	568	315	143	1,026
Weight of nitrogen .....do....	5.45	4.85	2.76	13.06
Per cent of nitrogen .....do....	.96	1.54	1.93	.....
Second day:				
Weight of urine .....grams..	502	258	203	963
Weight of nitrogen .....do....	5.37	4.31	3.59	13.27
Per cent of nitrogen .....do....	1.07	1.67	1.77	.....
Third day:				
Weight of urine .....grams..	461	427	193	1,081
Weight of nitrogen .....do....	5.44	5.64	3.45	14.53
Per cent of nitrogen .....do....	1.18	1.32	1.79	.....
Fourth day:				
Weight of urine .....grams..	455	323	213	991
Weight of nitrogen .....do....	5.78	4.55	3.71	14.04
Per cent of nitrogen .....do....	1.27	1.41	1.74	.....

During the third (rest) period the urine was also collected in portions corresponding to eight-hour intervals. The results follow:

TABLE 24.—Amount of nitrogen eliminated in the urine (digestion experiment No. 220).

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine .....grams..	780	350	173	1,303
Weight of nitrogen .....do....	6.24	4.73	2.73	13.70
Per cent of nitrogen .....do....	.80	1.35	1.58	.....
Second day:				
Weight of urine .....grams..	578	225	197	1,000
Weight of nitrogen .....do....	6.65	3.44	3.31	13.40
Per cent of nitrogen .....do....	1.15	1.53	1.68	.....
Third day:				
Weight of urine .....grams..	655	495	251	1,401
Weight of nitrogen .....do....	6.48	4.80	4.02	15.30
Per cent of nitrogen .....do....	.99	.97	1.60	.....
Fourth day:				
Weight of urine .....grams..	503	280	137	920
Weight of nitrogen .....do....	5.28	4.42	2.55	12.25
Per cent of nitrogen .....do....	1.05	1.58	1.86	.....

The daily balance of income and outgo of nitrogen was calculated. The results are shown in the following table:

TABLE 25.—*Daily income and outgo of nitrogen in experiment No. 21.*

Periods.	Time.	Nitrogen.			
		In food.	In feces.	In urine.	Gain.
	<i>Days.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
First period, rest.....	4	17.25	1.44	12.22	3.59
Second period, work.....	4	16.99	1.35	13.73	1.91
Third period, rest.....	4	16.95	1.41	13.66	1.88

### EXPERIMENT NO. 22.

The experimental conditions were the same in this as in the two preceding experiments. The subject was the same as in experiment No. 19. During the first and third periods the subject performed as little external muscular work as possible. During the second period a considerable amount of external muscular work was performed. This consisted in making 70 trips up and down a hill 140 feet high. The work expended in raising the body to the height of the hill was calculated to yield 1,319,799 foot-pounds, or 45,421 kilogrammeters. This is equivalent to a total of 106 calories, or an average of 24 calories per day. The details of the digestion experiment follow.

*Subject.*—Student C, 22 years of age.

*Weight (without clothing).*—At the beginning of the experiment, 65.5 kilograms (144 pounds); at the end of the first period and the beginning of the second period, 64.3 kilograms (141.5 pounds); at the close of the second and the beginning of the third period, 65 kilograms (143 pounds); at the end of the experiment, 64.3 kilograms (141.5 pounds).

*Duration.*—The experimental periods, each consisting of four days, began with breakfast on March 8, 12, and 16, respectively.

TABLE 26.—Results of experiment No. 22.

Laboratory number.	Food materials.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion calculated.
<b>FIRST PERIOD (REST).</b>									
<i>Digestion experiment No. 221.</i>									
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
449	Eggs.....	556	134	11.56	72	62	.....	6	.....
508	Butter.....	40	36	.10	1	35	.....	1	.....
504	Milk.....	6,000	781	34.80	218	283	280	48	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	320	288	7.84	49	23	216	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
507	Bread.....	840	565	12.68	79	11	475	8	.....
506	Potato chips.....	160	147	1.92	12	59	76	7	.....
	Sugar.....	320	320	.....	.....	.....	320	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....	.....	2,480	71.41	447	473	1,560	77	13,446
513	Feces (water-free).....	113	88	5.32	33	36	19	25	457
	Urine.....	5,338	.....	56.94	.....	.....	.....	.....	517
	Amount digested.....	.....	2,392	66.09	414	437	1,541	52	12,472
	Coefficients of digestibility (per cent).....	.....	96.5	92.6	92.6	92.4	98.8	67.5	92.8
<b>SECOND PERIOD (WORK).</b>									
<i>Digestion experiment No. 222.</i>									
449	Eggs.....	556	134	11.56	72	62	.....	6	.....
508	Butter.....	180	160	.43	3	157	.....	5	.....
515	Milk.....	5,408	703	30.28	189	268	246	41	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	320	288	7.84	49	23	216	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
507	Bread.....	1,000	672	15.10	94	12	566	10	.....
506	Potato chips.....	220	202	2.64	16	81	105	9	.....
	Sugar.....	500	500	.....	.....	.....	500	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....	.....	2,868	70.36	439	603	1,826	78	15,726
518	Feces (water-free).....	114	92	5.23	33	41	18	22	499
	Urine.....	4,146	.....	62.45	.....	.....	.....	.....	507
	Amount digested.....	.....	2,776	65.13	406	562	1,808	56	14,720
	Coefficients of digestibility (per cent).....	.....	96.8	92.6	92.5	93.2	99.0	71.8	93.6
<b>THIRD PERIOD (REST).</b>									
<i>Digestion experiment No. 223.</i>									
449	Eggs.....	556	134	11.56	72	62	.....	6	.....
508	Butter.....	40	36	.10	1	35	.....	1	.....
520	Milk.....	6,000	797	33.60	210	296	291	45	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	320	288	7.84	49	23	216	6	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
507	Bread.....	840	565	12.68	79	11	475	8	.....
506	Potato chips.....	160	147	1.92	12	59	76	7	.....
	Sugar.....	320	320	.....	.....	.....	320	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....	.....	2,496	70.21	439	486	1,571	74	13,568
523	Feces (water-free).....	107	83	5.16	32	27	24	24	431
	Urine.....	5,996	.....	62.09	.....	.....	.....	.....	509
	Amount digested.....	.....	2,413	65.05	407	459	1,547	50	12,628
	Coefficients of digestibility (per cent).....	.....	96.7	92.6	92.7	94.4	98.5	67.6	93.1



In the first (rest) period of this experiment the urine was collected in a single portion for each day. On the first day 952 grams was excreted, containing 1.39 per cent, or 13.2 grams nitrogen; the amount eliminated on the second day was 1,457 grams, with a nitrogen content of 0.96 per cent, or 14 grams; on the third day 1,537 grams, with a nitrogen content of 0.91 per cent, or 14 grams; and on the fourth day 1,392 grams, containing 1.13 per cent, or 15.7 grams nitrogen. The total nitrogen eliminated in the urine during the whole period was, therefore, 56.9 grams, or 14.2 grams per day. During the second (work) period the urine was collected in portions corresponding to eight-hour intervals, and its nitrogen content determined. The results are shown in the following table:

TABLE 27.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 222).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine .....grams..	317	340	197	854
Weight of nitrogen.....do....	4.85	5.95	4.26	15.06
Per cent of nitrogen .....	1.53	1.75	2.16	.....
Second day:				
Weight of urine .....grams..	335	260	255	850
Weight of nitrogen.....do....	5.90	4.76	5.23	15.89
Per cent of nitrogen .....	1.76	1.83	2.05	.....
Third day:				
Weight of urine .....grams..	417	343	291	1,051
Weight of nitrogen.....do....	6.05	5.73	4.54	16.32
Per cent of nitrogen .....	1.45	1.67	1.56	.....
Fourth day:				
Weight of urine .....grams..	712	409	270	1,391
Weight of nitrogen.....do....	6.34	4.87	3.97	15.18
Per cent of nitrogen .....	.89	1.19	1.47	.....



During the third (rest) period the urine was as before collected in portions corresponding to eight-hour intervals. The amounts eliminated and the nitrogen in it are shown in Table 28, which follows:

TABLE 28.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 223).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine .....	532	639	457	1,628
Weight of nitrogen.....	5.75	5.50	4.43	15.68
Per cent of nitrogen .....	1.08	.86	.97	.....
Second day:				
Weight of urine .....	575	817	363	1,755
Weight of nitrogen.....	4.95	6.54	4.10	15.59
Per cent of nitrogen .....	.86	.80	1.13	.....
Third day:				
Weight of urine .....	502	635	470	1,607
Weight of nitrogen.....	5.77	4.70	5.55	16.02
Per cent of nitrogen .....	1.15	.74	1.18	.....
Fourth day:				
Weight of urine .....	365	369	272	1,006
Weight of nitrogen.....	5.29	5.54	3.97	14.80
Per cent of nitrogen .....	1.45	1.50	1.46	.....

As was the case in the preceding experiments, the daily balance of income and outgo of nitrogen was determined.

TABLE 29.—*Daily income and outgo of nitrogen in experiment No. 22.*

Periods.	Time.	Nitrogen.			
		In food.	In feces.	In urine.	Gain.
	Days.	Grams.	Grams.	Grams.	Grams.
First period (rest) .....	4	17.85	1.33	14.24	2.28
Second period (work) .....	4	17.59	1.31	15.61	.67
Third period (rest) .....	4	17.55	1.29	15.52	.74

### EXPERIMENT NO. 23.

This experiment began the third series reported in the present publication, which was made with the same young men who had served as subjects of the preceding experiments. The diet contained less protein and energy than normal and was unchanged during the second or work period. Except in the second period, no appreciable amount of muscular work was performed. During the second period the subject of experiment No. 20 made the trip uphill 55 times. This was calculated to yield 1,201,915 foot-pounds, or 41,565 kilogrammeters, equivalent to a total of 97 calories, or an average of 24 calories per day. The average results of the digestion experiment follow:

*Subject.*—Chemist A, age 30 years.

*Weight (without clothing).*—At the beginning of the experiment was 69.8 kilograms (153.5 pounds); at the end of the first period and the beginning of the second period, 68.4 kilograms (150.5 pounds); at the close of the second and the beginning of the third period, 67.7 kilograms (149 pounds); at the close of the experiment, 67.3 kilograms (148 pounds).

*Duration.*—The three experimental periods, each of four days' duration, began with breakfast March 22, 26, and 30, respectively.

TABLE 30.—Results of experiment No. 23.

Laboratory number.	Food materials.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion calculated.
<b>FIRST PERIOD (REST).</b>									
<i>Digestion experiment No. 224.</i>									
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
449	Eggs.....	364	88	7.57	47	41	.....	4	.....
528	Butter.....	80	70	.24	2	68	.....	2	.....
525	Milk.....	7,600	966	41.80	261	353	352	59	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	280	252	6.86	43	20	189	5	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
527	Bread.....	900	604	14.31	90	11	503	10	.....
526	Potato chips.....	40	36	.50	3	13	20	2	.....
	Sugar.....	320	320	.....	.....	.....	320	.....	.....
	Coffee.....	800	2	.32	2	.....	.....	.....	.....
	Total.....	.....	2,546	73.95	463	506	1,577	83	13,917
531	Feces (water-free)	117	85	5.74	36	21	28	32	441
	Urine.....	6,533	.....	66.75	.....	.....	.....	.....	534
	Amount digested.....	.....	2,461	68.21	427	485	1,549	51	12,942
	Coefficients of digestibility (per cent).....	.....	96.7	92.2	92.2	95.9	98.2	61.5	93.0
<b>SECOND PERIOD (WORK).</b>									
<i>Digestion experiment No. 225.</i>									
449	Eggs.....	364	88	7.57	47	41	.....	4	.....
528	Butter.....	80	70	.24	2	68	.....	2	.....
535	Milk.....	7,600	976	41.04	257	353	366	55	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	280	252	6.86	43	20	189	5	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
527	Bread.....	900	604	14.31	90	11	503	10	.....
526	Potato chips.....	40	36	.50	3	13	20	2	.....
	Sugar.....	320	320	.....	.....	.....	320	.....	.....
	Coffee.....	800	2	.32	2	.....	.....	.....	.....
	Total.....	.....	2,556	73.19	459	506	1,591	79	13,951
536	Feces (water-free)	118	87	5.82	36	24	27	31	471
	Urine.....	4,274	.....	62.87	.....	.....	.....	.....	529
	Amount digested.....	.....	2,469	67.37	423	482	1,564	48	12,951
	Coefficients of digestibility (per cent).....	.....	96.6	92.0	92.2	95.3	98.3	60.8	92.8
<b>THIRD PERIOD (REST).</b>									
<i>Digestion experiment No. 226.</i>									
449	Eggs.....	364	88	7.57	47	41	.....	4	.....
528	Butter.....	80	70	.24	2	68	.....	2	.....
540	Milk.....	7,600	1,005	41.04	257	381	367	60	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	280	252	6.86	43	20	189	5	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
527	Bread.....	900	604	14.31	90	11	503	10	.....
526	Potato chips.....	40	36	.50	3	13	20	2	.....
	Sugar.....	320	320	.....	.....	.....	320	.....	.....
	Coffee.....	800	2	.32	2	.....	.....	.....	.....
	Total.....	.....	2,585	73.19	459	534	1,592	84	14,219
541	Feces (water-free)	121	88	5.88	37	26	25	33	457
	Urine.....	5,988	.....	68.35	.....	.....	.....	.....	527
	Amount digested.....	.....	2,497	67.31	422	508	1,567	51	13,235
	Coefficients of digestibility (per cent).....	.....	96.6	92.0	91.9	95.1	98.4	60.7	93.1

During the first (rest) period of this set of experiments the urine was collected in a single portion for each day. On the first day the total amount of urine eliminated was 1,405 grams, its nitrogen content 1.25 per cent, or 17.6 grams; on the second day, 1,913 grams urine, containing 0.86 per cent, or 16.4 grams; on the third day, 1,118 grams urine, containing 1.39 per cent, or 15.5 grams; and on the fourth day, 2,097 grams urine, containing 0.82 per cent, or 17.2 grams. The total nitrogen eliminated during the period was, therefore, 66.7 grams, or an average 16.7 grams per day. As in previous experiments, the urine was collected during the second or work period in portions corresponding to eight-hour intervals. The table following shows amount of urine and the nitrogen in it:

TABLE 31.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 225).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine .....grams..	333	300	352	985
Weight of nitrogen .....do....	4.33	5.19	5.56	15.08
Per cent of nitrogen.....	1.30	1.73	1.58	.....
Second day:				
Weight of urine .....grams..	370	233	497	1,100
Weight of nitrogen .....do....	5.18	4.12	6.51	15.81
Per cent of nitrogen.....	1.40	1.77	1.31	.....
Third day:				
Weight of urine .....grams..	457	293	380	1,130
Weight of nitrogen .....do....	5.12	4.81	5.28	15.21
Per cent of nitrogen.....	1.12	1.64	1.39	.....
Fourth day:				
Weight of urine .....grams..	355	325	379	1,059
Weight of nitrogen .....do....	4.97	5.85	5.95	16.77
Per cent of nitrogen.....	1.40	1.80	1.57	.....

The table below shows the urine and its nitrogen content eliminated in the different periods of the third (rest) period:

TABLE 32.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 226).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine .....grams..	300	350	618	1,268
Weight of nitrogen.....do....	4.80	6.06	7.29	18.15
Per cent of nitrogen.....	1.60	1.73	1.18	.....
Second day:				
Weight of urine .....grams..	405	368	850	1,623
Weight of nitrogen.....do....	5.02	5.59	6.55	17.16
Per cent of nitrogen.....	1.24	1.52	.77	.....
Third day:				
Weight of urine .....grams..	427	615	797	1,839
Weight of nitrogen.....do....	4.74	6.03	6.85	17.62
Per cent of nitrogen.....	1.11	.98	.86	.....
Fourth day:				
Weight of urine .....grams..	330	336	592	1,258
Weight of nitrogen.....do....	3.89	5.14	6.39	15.42
Per cent of nitrogen.....	1.18	1.53	1.08	.....

The daily balance of income and outgo of nitrogen in the three periods of the above experiment follows:

TABLE 33.—*Daily income and outgo of nitrogen in experiment No. 23.*

Periods.	Time.	Nitrogen.			
		In food.	In feces.	In urine.	Gain (+) or loss (-).
	<i>Days.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
First period, rest .....	4	18.49	1.44	16.69	+0.36
Second period, work .....	4	18.30	1.46	15.72	+1.12
Third period, rest .....	4	18.30	1.47	17.09	— .26

### EXPERIMENT NO. 24.

The experimental conditions in this were the same as in the preceding experiment. The subject performed during the second or work period 1,349,157 foot-pounds, or 46,717 kilogrammeters of estimated muscular work. This was equivalent to 109 calories, or 27 calories per day. As in previous cases, the work consisted in walking up and down hill. The number of trips made was 75.

*Subject.*—Chemist B, age 23 years.

*Weight (without clothing).*—At the beginning of the experiment 56.1 kilograms (123.5 pounds); at the end of the first period and the beginning of the second period, 55.9 kilograms (123 pounds); at the end of the second and the beginning of the third period, 55.6 kilograms (122 $\frac{1}{4}$  pounds); at the end of the experiment, 55.8 kilograms (122 $\frac{3}{4}$  pounds).

*Duration.*—The three experimental periods, each of four days' duration, began with breakfast, respectively March 23, 26, and 30.



TABLE 34.—Results of experiment No. 24.

Laboratory number.	Food materials.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion calculated.
<b>FIRST PERIOD (REST).</b>									
<i>Digestion experiment No. 227.</i>									
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
449	Eggs.....	608	147	12.65	79	68		6	
528	Butter.....	80	70	.24	2	68		2	
525	Milk.....	5,600	712	30.80	193	260	259	43	
480	Gelatin.....	100	99	.75	5		94		
505	Oatmeal.....	280	252	6.86	43	20	189	5	
485	Rice.....	120	109	1.60	10		99	1	
527	Bread.....	700	470	11.13	70	9	391	7	
526	Potato chips.....	80	74	1.00	6	27	41	4	
	Sugar.....	500	500				500		
	Coffee.....	400	1	.16	1				
	Total.....		2,434	65.19	409	452	1,573	68	13,088
532	Feces (water-free)	101	78	5.14	32	19	27	23	405
	Urine.....	4,944		50.11					471
	Amount digested.		2,356	60.05	377	433	1,546	45	12,212
	Coefficients of digestibility (per cent).....		96.8	92.1	92.2	95.8	98.3	66.2	93.3
<b>SECOND PERIOD (WORK).</b>									
<i>Digestion experiment No. 228.</i>									
449	Eggs.....	608	147	12.65	79	68		6	
528	Butter.....	80	70	.24	2	68		2	
535	Milk.....	5,600	719	30.24	189	260	270	41	
480	Gelatin.....	100	99	.75	5		94		
505	Oatmeal.....	280	252	6.86	43	20	189	5	
485	Rice.....	120	109	1.60	10		99	1	
527	Bread.....	700	470	11.13	70	9	391	7	
526	Potato chips.....	80	74	1.00	6	27	41	4	
	Sugar.....	500	500				500		
	Coffee.....	400	1	.16	1				
	Total.....		2,441	64.63	405	452	1,584	66	13,111
537	Feces (water-free)	105	82	5.38	33	29	20	22	444
	Urine.....	3,894		52.42					465
	Amount digested.		2,359	59.25	372	423	1,564	44	12,202
	Coefficients of digestibility (per cent).....		96.7	91.7	91.9	93.6	98.7	66.7	93.1
<b>THIRD PERIOD (REST).</b>									
<i>Digestion experiment No. 229.</i>									
449	Eggs.....	608	147	12.65	79	68		6	
528	Butter.....	80	70	.24	2	68		2	
540	Milk.....	5,600	740	30.24	189	281	270	44	
480	Gelatin.....	100	99	.75	5		94		
505	Oatmeal.....	280	252	6.86	43	20	189	5	
485	Rice.....	120	109	1.60	10		99	1	
527	Bread.....	700	470	11.13	70	9	391	7	
526	Potato chips.....	80	74	1.00	6	27	41	4	
	Sugar.....	500	500				500		
	Coffee.....	400	1	.16	1				
	Total.....		2,462	64.63	405	473	1,584	69	13,308
542	Feces (water-free)	106	84	5.51	34	29	21	22	436
	Urine.....	4,225		56.75					464
	Amount digested.		2,378	59.12	371	444	1,563	47	12,408
	Coefficients of digestibility (per cent).....		96.6	91.5	91.6	93.9	98.7	68.1	93.2



On the first day of the first (rest) period the urine excreted amounted to 1,324 grams, with a nitrogen content of 0.79 per cent, or 10.5 grams; on the second day the amount of urine was 1,073 grams, its nitrogen content 1.07 per cent, or 11.7 grams; on the third day the subject excreted 1,130 grams urine, containing 1.20 per cent, or 13.6 grams nitrogen; and on the fourth day 1,397 grams urine, containing 1.03 per cent, or 14.4 grams. The total nitrogen excreted in the period was, therefore, 50.2 grams, the average amount per day 12.5 grams. In the second (work) period the urine was collected in portions corresponding to eight-hour intervals. The details of the amounts of urine and nitrogen in it follow:

TABLE 35.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 228).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine.....grams..	455	466	193	1,114
Weight of nitrogen.....do....	4.32	4.66	2.90	11.88
Per cent of nitrogen.....	.95	1.00	1.50	.....
Second day:				
Weight of urine.....grams..	408	418	183	1,009
Weight of nitrogen.....do....	4.57	5.43	2.85	12.85
Per cent of nitrogen.....	1.12	1.30	1.55	.....
Third day:				
Weight of urine.....grams..	341	290	220	851
Weight of nitrogen.....do....	4.81	4.64	4.14	13.59
Per cent of nitrogen.....	1.41	1.60	1.88	.....
Fourth day:				
Weight of urine.....grams..	345	339	236	920
Weight of nitrogen.....do....	4.69	4.95	4.46	14.10
Per cent of nitrogen.....	1.36	1.46	1.89	.....

The amount of urine excreted in the different periods of the third (rest) period, together with its nitrogen content, is shown in the following table:

TABLE 36.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 229).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 p. m.	Total.
First day:				
Weight of urine.....grams..	373	433	214	1,020
Weight of nitrogen.....do....	5.00	5.59	3.85	14.44
Per cent of nitrogen.....	1.34	1.29	1.80	.....
Second day:				
Weight of urine.....grams..	465	426	195	1,086
Weight of nitrogen.....do....	5.35	5.50	3.74	14.59
Per cent of nitrogen.....	1.15	1.29	1.92	.....
Third day:				
Weight of urine.....grams..	384	410	218	1,012
Weight of nitrogen.....do....	4.92	5.13	4.14	14.19
Per cent of nitrogen.....	1.28	1.25	1.90	.....
Fourth day:				
Weight of urine.....grams..	438	465	204	1,107
Weight of nitrogen.....do....	4.95	5.07	3.51	13.53
Per cent of nitrogen.....	1.13	1.09	1.72	.....

Following the same methods as before, the daily income and outgo of nitrogen was calculated. The nitrogen balance follows:

TABLE 37.—*Daily income and outgo of nitrogen in experiment No. 24.*

Periods.	Time.	Nitrogen.			
		In food.	In feces.	In urine.	Gain.
	<i>Days.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
First period (rest) .....	4	16.30	1.29	12.53	2.48
Second period (work) .....	4	16.16	1.35	13.11	1.70
Third period (rest) .....	4	16.16	1.38	14.19	.59

### EXPERIMENT NO. 25.

This experiment was made under the same experimental conditions as the two immediately preceding. The muscular work performed during the second period consisted in making the trip up and down hill 75 times, which yielded according to the method of calculation followed, 1,409,119 foot-pounds, or 48,849 kilogrammeters. This was calculated to be equal to a total of 114 calories, or 18 calories per day.

*Subject.*—Student C, age 22 years.

*Weight (without clothing).*—At the beginning of the experiment 64.1 kilograms (141 pounds). The weight did not change during the first and second period. At the end of the third period it was 64.6 kilograms (142 pounds).

*Duration.*—The three experimental periods, each of four days' duration, began with breakfast March 22, 26, and 30, respectively.

TABLE 38.—Results of experiment No. 25.

Laboratory number.	Food materials.	Weight of material.	Total organic matter.	Nitrogen.	Protein.	Fat.	Carbohydrates.	Ash.	Heat of combustion calculated.
<b>FIRST PERIOD (REST).</b>									
<i>Digestion experiment No. 230.</i>									
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>
449	Eggs.....	584	141	12.15	76	65	.....	6	.....
528	Butter.....	80	70	.24	2	68	.....	2	.....
525	Milk.....	5,600	712	30.80	193	260	259	43	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	280	252	6.86	43	20	189	5	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
527	Bread.....	900	604	14.31	90	11	503	10	.....
526	Potato chips.....	160	147	2.00	12	53	82	8	.....
	Sugar.....	500	500	.....	.....	.....	500	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....		2,635	68.87	432	477	1,726	75	14,089
533	Feces (water-free)	90	68	4.37	27	15	26	22	353
	Urine.....	4,514	.....	61.24	.....	.....	.....	.....	506
	Amount digested.....		2,567	64.50	405	462	1,700	53	13,230
	Coefficients of digestibility (per cent).....		97.4	93.7	93.8	96.9	98.5	70.7	93.9
<b>SECOND PERIOD (WORK).</b>									
<i>Digestion experiment No. 231.</i>									
449	Eggs.....	584	141	12.15	76	65	.....	6	.....
528	Butter.....	80	70	.24	2	68	.....	2	.....
535	Milk.....	5,600	719	30.24	189	260	270	41	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	280	252	6.86	43	20	189	5	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
527	Bread.....	900	604	14.31	90	11	503	10	.....
526	Potato chips.....	160	147	2.00	12	53	82	8	.....
	Sugar.....	500	500	.....	.....	.....	500	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....		2,642	68.31	428	477	1,737	73	14,112
538	Feces (water-free)	100	77	5.02	31	28	18	22	417
	Urine.....	3,264	.....	59.40	.....	.....	.....	.....	496
	Amount digested.....		2,565	63.29	397	449	1,719	51	13,199
	Coefficients of digestibility (per cent).....		97.1	92.7	92.8	94.1	99.0	69.9	93.5
<b>THIRD PERIOD (REST).</b>									
<i>Digestion experiment No. 232.</i>									
449	Eggs.....	584	141	12.15	76	65	.....	6	.....
528	Butter.....	80	70	.24	2	68	.....	2	.....
540	Milk.....	5,600	740	30.24	189	281	270	44	.....
480	Gelatin.....	100	99	.75	5	.....	94	.....	.....
505	Oatmeal.....	280	252	6.86	43	20	189	5	.....
485	Rice.....	120	109	1.60	10	.....	99	1	.....
527	Bread.....	900	604	14.31	90	11	503	10	.....
526	Potato chips.....	160	147	2.00	12	53	82	8	.....
	Sugar.....	500	500	.....	.....	.....	500	.....	.....
	Coffee.....	400	1	.16	1	.....	.....	.....	.....
	Total.....		2,663	68.31	428	498	1,737	76	14,308
543	Feces (water-free)	110	87	5.36	34	37	16	23	451
	Urine.....	3,732	.....	54.58	.....	.....	.....	.....	492
	Amount digested.....		2,576	62.95	394	461	1,721	53	13,365
	Coefficients of digestibility (per cent).....		96.7	92.2	92.1	92.6	99.1	69.7	93.4

On the first day of the first (rest) period the subject excreted 842 grams of urine, containing 1.92 per cent, or 16.2 grams nitrogen; on the second day 910 grams urine, containing 1.69 per cent, or 15.4 grams nitrogen; on the third day the total urine excreted equaled 1,065 grams, its nitrogen content 1.37 per cent, or 14.6 grams; on the fourth day of the period the urine excreted equaled 1,697 grams with a nitrogen content of 0.89 per cent, or 15.1 grams. The total amount of nitrogen excreted in the urine during the period was, therefore, 61.2 grams; or 15.3 grams per day.

As was the case during the preceding experiments, the urine was collected in the second (work) period in portions corresponding to eight-hour intervals, and its nitrogen content determined. The results follow.

TABLE 39.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 231).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine.....grams..	344	335	190	869
Weight of nitrogen.....do....	4.44	5.39	3.84	13.67
Per cent of nitrogen.....do....	1.29	1.61	2.02	.....
Second day:				
Weight of urine.....grams..	299	387	165	851
Weight of nitrogen.....do....	5.17	7.20	3.48	15.85
Per cent of nitrogen.....do....	1.78	1.86	2.11	.....
Third day:				
Weight of urine.....grams..	270	308	155	733
Weight of nitrogen.....do....	5.02	5.85	3.58	14.45
Per cent of nitrogen.....do....	1.86	1.90	2.31	.....
Fourth day:				
Weight of urine.....grams..	277	319	215	811
Weight of nitrogen.....do....	5.18	6.06	4.19	15.43
Per cent of nitrogen.....do....	1.87	1.90	1.95	.....

The details of the amount of urine and nitrogen in it excreted during the eight-hour periods of the third (rest) period of this experiment are as follows:

TABLE 40.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 232).*

Period.	8 a. m. to 4 p. m.	4 p. m. to 12 p. m.	12 p. m. to 8 a. m.	Total.
First day:				
Weight of urine.....grams..	322	480	380	1,182
Weight of nitrogen.....do....	5.22	6.38	3.50	15.10
Per cent of nitrogen.....do....	1.62	1.33	.92	.....
Second day:				
Weight of urine.....grams..	562	322	235	1,119
Weight of nitrogen.....do....	6.18	4.93	3.67	14.78
Per cent of nitrogen.....do....	1.10	1.53	1.56	.....
Third day:				
Weight of urine.....grams..	180	365	175	720
Weight of nitrogen.....do....	2.75	5.62	3.40	11.77
Per cent of nitrogen.....do....	1.53	1.54	1.94	.....
Fourth day:				
Weight of urine.....grams..	242	304	215	761
Weight of nitrogen.....do....	4.02	5.02	3.89	12.93
Per cent of nitrogen.....do....	1.66	1.65	1.81	.....



The table below shows the daily balance of income and outgo of nitrogen during the whole experiment:

TABLE 41.—*Daily income and outgo of nitrogen in experiment No. 25.*

Periods.	Time.	Nitrogen.			
		In food.	In feces.	In urine.	Gain.
First period, rest.....	Days.	Grams.	Grams.	Grams.	Grams.
Second period, work.....	4	17.22	1.09	15.31	0.82
Third period, rest.....	4	17.08	1.26	14.85	.97
	4	17.08	1.34	13.65	2.09

## SUMMARY OF COEFFICIENTS OF DIGESTIBILITY.

In the preceding pages data are given which show the amount of protein, fat, and carbohydrates digested, as well as the energy of the total digested food. Such data are summarized in Table 42, the results being compared with those obtained in the similar investigation previously reported.<sup>a</sup>

TABLE 42.—*Summary of coefficients of digestibility of a simple mixed diet, and the energy available.*

Number of experiment.	Subject.	Character of experiment.	Protein.	Fat.	Carbohydrates.	Energy.
			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
206	A	Rest.....	91.6	95.9	97.7	92.6
207	A	Work.....	91.2	96.4	97.8	92.7
208	A	Rest.....	92.2	96.7	97.9	93.0
209	B	.....do.....	92.0	94.0	98.3	93.0
210	B	Work.....	91.5	94.0	98.4	92.9
211	B	Rest.....	91.5	94.1	98.4	93.0
212	C	.....do.....	92.4	94.3	98.3	93.1
213	C	Work.....	92.6	92.7	98.6	93.0
214	C	Rest.....	92.9	94.8	98.4	93.4
215	A	.....do.....	92.2	94.2	98.4	92.5
216	A	Work.....	91.6	95.5	98.4	93.3
217	A	Rest.....	91.4	95.2	98.1	92.6
218	B	.....do.....	91.7	92.4	98.8	92.5
219	B	Work.....	92.0	93.8	99.1	93.6
220	B	Rest.....	91.7	93.0	98.7	92.7
221	C	.....do.....	92.6	92.4	98.8	92.8
222	C	Work.....	92.5	93.2	99.0	93.6
223	C	Rest.....	92.7	94.4	98.5	93.1
224	A	.....do.....	92.2	95.9	98.2	93.0
225	A	Work.....	92.2	95.3	98.3	92.8
226	A	Rest.....	91.9	95.1	98.4	93.1
227	B	.....do.....	92.2	95.8	98.3	93.3
228	B	Work.....	91.9	93.6	98.7	93.1
229	B	Rest.....	91.6	93.9	98.7	93.2
230	C	.....do.....	93.8	96.9	98.5	93.9
231	C	Work.....	92.8	94.1	99.0	93.5
232	C	Rest.....	92.1	92.6	99.1	93.4
Average, rest experiments:						
	A, 6 experiments.....		91.9	95.5	98.1	92.8
	B, 6 experiments.....		91.8	93.9	98.5	93.0
	C, 6 experiments.....		92.7	94.2	98.6	93.3
Average, 18 experiments.....			92.2	94.5	98.4	93.0
Average, work experiments:						
	A, 3 experiments.....		91.7	95.7	98.2	92.9
	B, 3 experiments.....		91.8	93.8	98.7	93.2
	C, 3 experiments.....		92.6	93.3	98.9	93.4
Average, 9 experiments.....			92.0	94.3	98.6	93.2
Average, all (27) experiments.....			92.1	94.5	98.5	93.1

<sup>a</sup> U. S. Dept. Agr., Office of Experiment Stations Bul. 89.



From the table it appears that there was practically no difference in the average thoroughness of digestion of the ration when the subjects rested and when they performed rather severe muscular work. Slight variations are noticeable in the coefficients of digestibility obtained with the different subjects, but these are not sufficient for general deductions. Individuality appeared to have much less effect upon the digestion than might be expected. The average results agree quite closely with those previously obtained when it is remembered that the diet in the two series of experiments though similar was not the same. Considering the experiments as a whole, the differences in coefficients of digestibility between the periods of work and rest are less marked than those observed when the conditions as regards work performed were uniform. This is strong evidence that the average results of a considerable number of digestion experiments may be assumed to actually represent the digestibility of the different nutrients in a given diet, and that such averages may be used in calculation.

### **METABOLISM OF NITROGEN.**

The income and outgo of nitrogen was determined in the experiments reported in this bulletin, the special object being to secure information regarding the nutrients, which are the actual source of muscular work. It was assumed that if protein was required for performing external muscular work more nitrogen would be excreted in the urine under the experimental conditions in the period in which muscular work was performed than in the periods in which the subject remained as inactive as possible. There are those who maintain that muscular work is performed at the expense of nitrogen-free nutrients, and that under ordinary circumstances protein is not the source of energy, but is required for the formation and repair of body tissue. Other physiologists hold that while nitrogen-free nutrients are usually the source of muscular energy, yet, if the work is protracted enough, or severe enough to induce labored breathing, the energy must be supplied by protein. Judging by the results of the investigations conducted under the auspices of this Department, it appears that, provided the carbohydrates and fat in the diet are abundant and the protein is not excessive, the nitrogen-free nutrients are the usual source of energy for external muscular work.

In the early experiments made at the University of Tennessee the diet was quite abundant, and under the different experimental conditions little change in the amount of nitrogen excreted in the urine was observed, which could be attributed to an increased metabolism of protein in the work periods. In the present experiments the diet was more limited in amount, though in the majority of cases it was normal in the proportion of nitrogen-free to nitrogenous nutrients.

The balance of income and outgo of nitrogen, as well as the available energy in a food, and the average heat equivalent of the work performed in the different work experiments, is shown in the following table:

TABLE 43.—*Daily income and outgo of nitrogen and energy in metabolism experiments Nos. 17-25, with work actually measured.*

Metabolism experiment number.	Digestion experiment number.	Character of experiment.	Subject.	Average change in body weight.	Nitrogen.					Energy.				Work measured.	
					In food.	In feces.	In urine.	Gain (+) or loss (-).		In food.	In feces.	In urine.	Available.	Amount.	Heat equivalent.
				Kgs.	Gms.	Gms.	Gms.	Gms.	Calo-ries.	Calo-ries.	Calo-ries.	Calo-ries.		Kgms.	Calo-ries.
17	206	Rest	A	-0.45	20.88	1.75	17.56	+1.57	3,960	143	149	3,668			
	207	Work	A		20.08	1.74	17.92	+ .42	3,912	142	143	3,627		55,876	130.4
	208	Rest	A		20.48	1.60	17.61	+1.27	3,898	124	148	3,626			
18	209	Rest	B	+ .34	18.54	1.51	13.01	+4.02	3,687	126	133	3,428			
	210	Work	B	+ .34	17.94	1.51	14.28	+2.15	3,651	133	128	3,390		48,849	114.0
	211	Rest	B	+ .23	18.24	1.57	14.18	+2.49	3,640	126	130	3,384			
19	212	Rest	C	- .23	18.93	1.44	14.29	+3.20	3,848	128	137	3,583			
	213	Work	C		18.33	1.37	16.44	+ .52	3,812	134	132	3,546		50,992	119.0
	214	Rest	C		18.63	1.35	16.77	+ .51	3,802	116	136	3,550			
20	215	Rest	A	-1.13	19.43	1.52	17.98	- .07	3,442	119	140	3,183			
	216	Work	A		19.07	1.59	16.75	+ .73	4,016	133	136	3,747		39,421	92.0
	217	Rest	A		19.04	1.62	17.45	+ .03	3,483	123	136	3,224			
21	218	Rest	B	- .45	17.25	1.44	12.22	+3.59	3,175	114	124	2,937			
	219	Work	B	+ .45	16.99	1.35	13.73	+1.91	3,748	118	122	3,508		42,422	99.0
	220	Rest	B	- .23	16.95	1.41	13.66	+1.88	3,206	113	121	2,972			
22	221	Rest	C	-1.13	17.85	1.33	14.24	+2.28	3,361	114	129	3,118			
	222	Work	C	+ .68	17.59	1.31	15.61	+ .67	3,982	125	127	3,680		45,421	106.0
	223	Rest	C	- .68	17.55	1.29	15.52	+ .74	3,392	108	127	3,157			
23	224	Rest	A	-1.36	18.49	1.44	16.69	+ .86	3,479	110	133	3,236			
	225	Work	A	- .23	18.30	1.46	15.72	+1.12	3,488	118	132	3,238		41,565	97.0
	226	Rest	A	- .45	18.30	1.47	17.09	- .26	3,555	114	132	3,309			
24	227	Rest	B	- .34	16.30	1.29	12.53	+2.48	3,272	101	118	3,053			
	228	Work	B	- .34	16.16	1.35	13.11	+1.70	3,278	111	116	3,031		46,717	109.0
	229	Rest	B	+ .23	16.16	1.38	14.19	+ .59	3,327	109	116	3,102			
25	230	Rest	C		17.22	1.09	15.31	+ .82	3,522	88	126	3,308			
	231	Work	C		17.08	1.23	14.85	+ .97	3,528	104	124	3,300		48,849	114.0
	232	Rest	C	+ .45	17.08	1.34	13.65	+2.09	3,577	113	123	3,341			

No constant difference was observed in the amount of nitrogen excreted in the urine in different periods which could be attributed to the muscular work performed.

### COMPOSITE SAMPLES.

A considerable part of the labor involved in conducting experiments like those reported in this bulletin is due to the fact that each food material is analyzed. It was believed that if a composite sample was made up of aliquot portions of the different foods in any given ration the analysis of such sample would show the average composition of the ration as a whole. To determine the accuracy of this method, composite samples were made of the diet supplied in sixteen of the experiments reported in this and a former bulletin,<sup>a</sup> and the results

<sup>a</sup>U. S. Dept. Agr., Office of Experiment Stations Bul. 89.

compared with the average values for the ration computed from the analyses of the different foods composing it. Sugar was not included in the composite sample, and the data derived from the analysis of sugar are also omitted in computing the average composition of the ration from the analyses of individual foods. It was believed that this omission would not affect the value of the results, as sugar, of course, contains no nitrogen; furthermore, it was convenient to omit the sugar as at best the composite sample was bulky and therefore rather difficult to handle satisfactorily.

In experiments Nos. 53, 56, and 59 the ration consisted of Hamburg steak, butter, milk, oatmeal, bread, and potato chips. In experiments Nos. 62 and 65 the ration was made up of the same materials, except that Hamburg steak was omitted and cracked corn was added. The ration in experiments Nos. 99, 102, and 105 was made up of milk, oatmeal, potato chips, bread, canned beef, and butter. In experiment No. 108 the ration was the same in character, except that gelatin was added. Sugar was used in all the rations, but, as previously noted, was not included in the comparison. In some of the experiments coffee was taken as a beverage, but the amount of nutrients thus added to the ration is so small that it is believed that this material may be left out of account without introducing any appreciable error.

In nine of the tests (digestion experiments Nos. 53, 56, 59, 62, 65, 99, 102, 105, and 108)<sup>a</sup> one-fifth of the total amount of the several food materials was taken as an aliquot portion. In seven later tests (digestion experiments Nos. 147, 150, 153, 156, 159, 165, and 168) the proportion was diminished to one-tenth. In these tests the analyses of the composite samples were made in duplicate to study still further the accuracy of the method. It seemed probable that if the composite sample did not represent very closely the average composition of the ration, or, in other words, if it was not a uniform mixture, the duplicate analyses would not agree at all closely.

The materials making up the composite sample were thoroughly mixed and then dried, ground, subsampled, and analyzed in the usual way.

The calculated composition of the ration was learned by dividing the sum of the amounts of any given nutrient in the several foods by the total nutrients in the ration. Thus in experiment No. 53 the total weight of organic and mineral matters in the food, leaving out the sugar as already explained, was 1,252 grams. The total protein in the different articles making up the diet was 267 grams. Therefore the ration as a whole contained 21.33 per cent protein ( $267 \div 1,252 = 21.33$  per cent).

In Table 44 a comparison is made of the results obtained by analyz-

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<sup>a</sup> U. S. Dept. Agr., Office of Experiment Stations Bul. 89.



ing the composite samples of the several rations and by calculating their composition from the analysis of the several food materials.

TABLE 44.—*Quantities and proportions of nutrients in ration computed from composition of individual food materials and from that of the composite sample.*

Character of analyses.	Quantities of nutrients in ration for four days.				Percentage composition of water-free material.			
	Protein.	Fat.	Carbohy- drates.	Ash.	Protein.	Fat.	Carbohy- drates.	Ash.
Experiment No. 53:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Per cent.</i>	<i>Per ct.</i>	<i>Per cent.</i>	<i>Per ct.</i>
By individual analyses .	267	390	547	48	21.33	31.15	43.69	3.83
By composite analysis...	268	385	551	47	21.43	30.78	44.03	3.76
Experiment No. 56:								
By individual analyses .	273	296	545	44	23.91	25.45	46.86	3.78
By composite analysis...	282	296	539	46	24.21	25.48	46.37	3.94
Experiment No. 59:								
By individual analyses .	295	311	521	48	25.11	26.47	44.34	4.08
By composite analysis...	300	322	505	48	25.53	27.38	43.00	4.09
Experiment No. 62:								
By individual analyses .	218	271	456	38	22.18	27.56	46.39	3.87
By composite analysis...	218	266	460	39	22.22	27.03	46.77	3.98
Experiment No. 65:								
By individual analyses .	239	271	579	39	21.19	24.03	51.33	3.45
By composite analysis...	239	276	572	40	21.20	24.48	50.73	3.59
Experiment No. 99:								
By individual analyses .	248	279	570	42	21.77	24.50	50.04	3.69
By composite analysis...	263	271	566	38	23.13	23.82	49.70	3.35
Experiment No. 102:								
By individual analyses .	185	212	562	32	18.67	21.39	56.71	3.23
By composite analysis...	192	199	568	32	19.39	20.07	57.36	3.18
Experiment No. 105:								
By individual analyses .	210	243	563	35	19.98	23.12	53.57	3.33
By composite analysis...	226	239	550	36	21.47	22.79	52.34	3.40
Experiment No. 108:								
By individual analyses .	262	307	646	44	20.81	24.39	51.31	3.50
By composite analysis...	266	293	656	44	21.11	23.31	52.11	3.47
Experiment No. 206:								
By individual analyses .	522	559	1840	84	17.37	18.60	61.24	2.79
By composite analysis...	544	585	1781	95	18.10	19.46	59.27	3.17
Experiment No. 209:								
By individual analyses .	464	517	1751	73	16.54	18.43	62.43	2.60
By composite analysis...	486	532	1699	88	17.31	18.97	60.59	3.13
Experiment No. 212:								
By individual analyses .	473	521	1885	74	16.02	17.64	63.84	2.50
By composite analysis...	478	532	1856	87	16.20	18.01	62.85	2.94
Experiment No. 215:								
By individual analyses .	486	503	1517	86	18.75	19.40	58.53	3.32
By composite analysis...	494	493	1515	90	19.04	19.00	58.50	3.46
Experiment No. 218:								
By individual analyses .	432	461	1428	73	18.04	19.26	59.65	3.05
By composite analysis...	428	448	1443	75	17.87	18.73	60.26	3.14
Experiment No. 224:								
By individual analyses .	463	506	1577	83	17.61	19.25	59.99	3.15
By composite analysis...	473	470	1600	86	18.00	17.86	60.88	3.26
Experiment No. 227:								
By individual analyses .	409	452	1573	68	16.35	18.07	62.86	2.72
By composite analysis...	406	463	1565	68	16.21	18.50	62.56	2.73

It will be seen that the agreement between the composition of the ration as shown by the analysis of composite samples and as computed on the basis of analyses of individual foods is quite close. When the results of duplicate analyses of the same composite sample were compared the same close agreement is found. In accordance with the usual practice, these data are not reported. In all cases the discrepancies are not greater than are to be expected from the analysis of different samples of such foods as meat, fish, etc., or in some cases even in duplicate analyses of the same sample. Furthermore, it must be remembered that the calculated composition of the ration includes the result of all the errors in the analysis of the different foods. The proportion of error in the analysis of composite samples it would

appear must be lower, as the total number of determinations is not nearly as large.

It is interesting to compare the coefficients of digestibility obtained in the different work and rest periods in the earlier experiments at the University of Tennessee and those reported herewith when the composition of the ration is obtained by the two methods.

TABLE 45.—*Coefficients of digestibility of nutrients computed from composition of individual food materials and from that of composite samples.*

Character of analyses.	Protein.	Fat.	Carbohy- drates.	Ash.	Energy.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Experiment No. 53:					
By individual analyses .....	94.4	96.9	96.1	66.7	90.8
By composite analysis .....	94.4	96.9	96.2	66.0	.....
Experiment No. 56:					
By individual analyses .....	94.2	94.9	98.0	65.9	90.8
By composite analysis .....	94.3	94.9	98.0	67.4	.....
Experiment No. 59:					
By individual analyses .....	94.2	94.9	96.5	66.7	88.9
By composite analysis .....	94.3	95.0	96.5	66.7	.....
Experiment No. 62:					
By individual analyses .....	91.7	97.0	95.9	55.3	91.2
By composite analysis .....	91.8	97.0	95.9	56.4	.....
Experiment No. 65:					
By individual analyses .....	93.3	96.7	97.6	61.5	91.2
By composite analysis .....	93.3	96.8	97.6	62.5	.....
Experiment No. 99:					
By individual analyses .....	92.7	95.7	96.8	52.4	90.0
By composite analysis .....	93.2	95.6	96.8	47.4	.....
Experiment No. 102:					
By individual analyses .....	91.4	88.2	98.2	56.3	88.8
By composite analysis .....	91.7	87.4	98.2	56.3	.....
Experiment No. 105:					
By individual analyses .....	92.9	95.5	96.1	62.9	89.4
By composite analysis .....	93.4	95.4	96.0	63.9	.....
Experiment No. 108:					
By individual analyses .....	92.8	94.5	97.5	56.8	90.1
By composite analysis .....	92.9	94.2	97.6	56.8	.....
Experiment No. 206:					
By individual analyses .....	91.6	95.9	97.7	56.0	.....
By composite analysis .....	91.9	96.1	97.6	61.0	.....
Experiment No. 209:					
By individual analyses .....	92.0	94.0	98.3	67.1	.....
By composite analysis .....	92.4	94.2	98.3	72.7	.....
Experiment No. 212:					
By individual analyses .....	92.4	94.3	98.3	67.6	.....
By composite analysis .....	92.5	94.4	98.2	72.4	.....
Experiment No. 215:					
By individual analyses .....	92.2	94.2	98.4	58.1	.....
By composite analysis .....	92.3	94.1	98.4	60.0	.....
Experiment No. 218:					
By individual analyses .....	91.7	92.4	98.8	64.4	.....
By composite analysis .....	91.6	92.2	98.8	65.3	.....
Experiment No. 224:					
By individual analyses .....	92.2	95.9	98.2	61.5	.....
By composite analysis .....	92.4	95.5	98.3	62.8	.....
Experiment No. 227:					
By individual analyses .....	92.2	95.8	98.3	66.2	.....
By composite analysis .....	92.1	95.9	98.3	66.2	.....

The agreement between the results obtained by the two methods is again seen to be very close.

From the results of the above comparisons it seems fair to conclude that the composition of a given diet may be learned with reasonable accuracy by the analysis of a composite sample made up of aliquot portions of the different foods in the ration, and that this method may be advantageously followed in digestion experiments and similar investigations where the amount of analytical work is at best necessarily large.





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